EARTHEN STRUCTURES BUILT BY NYMPHS OF THE CICADA *CYCLOCHILA AUSTRALASIAE* (DONOVAN) (HOMOPTERA: CICADIDAE)

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Abstract

The construction of above ground earthen structures or turrets at the entrance of their burrows by cicada nymphs has been reported from North America, Africa and South-East Asia. This paper reports on the building of a turret and associated activity by an Australian cicada, *Cyclochila australasiae* (Donovan). Such activity is of interest to recent studies on the role that soil mesofauna play in modifying topsoils.

Introduction

Occasionally cicada nymphs build earthen structures projecting above their burrows. These structures have been termed a variety of names including: "adobe dwellings", "chimneys", "cicada cones", "cicada huts", "roofs", "towers" and "turrets" (Marlatt, 1907); "hollow clay tower" (McKeown, 1942) and "tower like domes" (Moulds, 1982). Myers (1929), in a major review of cicadas, favoured the term "turret" as did Musgrave (1923) in reference to an Australian example. In keeping with this brief tradition the latter term is used in this paper.

The first record of turrets appears to have been made by N. Potter in 1839 (in Marlatt, 1907) for the "periodical cicada", *Magicicada septendecim* (Marlatt) of eastern USA. Turrets were described also by Father Mason in 1860 from the Karen jungles of Burma (Theobald, 1882-83) and Myers (1929) refers to other observations from Thailand and the Cameroons. Within Australia, Musgrave (1923) and Moulds (1982) report on turrets built by the "greengrocer/yellow monday", *Cyclochila australasiae* (Donovan).

This note records observations, many of which are made for the first time, on the building of a turret and associated activity by an Australian cicada. The study formed part of a wider and more detailed investigation on the role of soil mesofauna (e.g. ants, earthworms and termites) on soil formation (Humphreys 1981, 1985, Humphreys and Mitchell 1983).

Preliminary Observations

The observations referred to here, except where stated otherwise, were made in a garden at Epping NSW where about 20 cicada burrows occurred at the base of some camphor laurel trees, *Cinnamomum camphora* (L.) Nees. These trees grew in a sandy clay loam to sandy

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clay textured soil with shale fragments developed on Wianamatta shales. The most common soil at this locality is a Red Podzolic with a clay loam topsoil. Meteorological conditions pertaining to these observations are presented in Table 1.

In order to secure information on turret construction a solitary turret was broken from its burrow and a plastic vial (37 mm diameter, 75 mm long), similar in size to the turret, was placed over the burrow with the open end facing downwards. This action was performed on 30 April 1978 at 1730 hours. On 4th May the vial, which was now lined with mud, was removed and the burrow was kept under continuous observation between 1015 and 1245 hours. (N.B. a bend in the burrow allowed only the upper 13 cm of a total length of 40 cm to be viewed directly). During this period nine pellets of mud were deposited by the nymph at or near the surface of the burrow (Fig. 1A). After completing these observations, the burrow was covered with a small box (16 x 16 cm, open-end facing down) and when next seen at 2220 hours on the same day the upper few centimetres of the burrow had been sealed with a layer of another sixteen pellets

TABLE 1. Climatic conditions at Marsfield Meteorological station (lat. 33°47'S, long. 151°07'E, elevation 60 m a.s.l.) at the time of the observations. This station is 4 km east of the Epping site. Mean annual rainfall 1178 mm; mean maximum temperature 22.4°C annual, 26.5°C in January and 16.8°C in July; mean minimum temperature 11.1°C annual, 16.7°C in January, 4.5°C in July.

Time (10 day periods 1978)	Mean max. temperature (°C)	Mean relative humidity (%)	Rainfall (mm)	Mean cloud cover (oktas)
Mar 11 - Mar 20	26.2	74.7	258.2	5.7
Mar 21 - Mar 30	25.4	73.4	62.0	5.2
Mar 31 - Apr 9	22.9	72.6	29.6	4.8
Apr 10 - Apr 19	22.8	74.1	29.6	3.8
Apr 20 - Apr 29	22.4	58.1	0.0	2.2
Apr 30 - May 9*	24.3	84.8	0.8	1.7
May 10 - May 19	17.9	74.1	30.0	5.1
May 20 - May 29	20.8	74.1	109.8	3.8
May 30 - Jun 8	18.2	68.4	169.8	2.7
Jun 9 - Jun 18	15.9	72.0	63.0	4.5

* Period of nymph activity

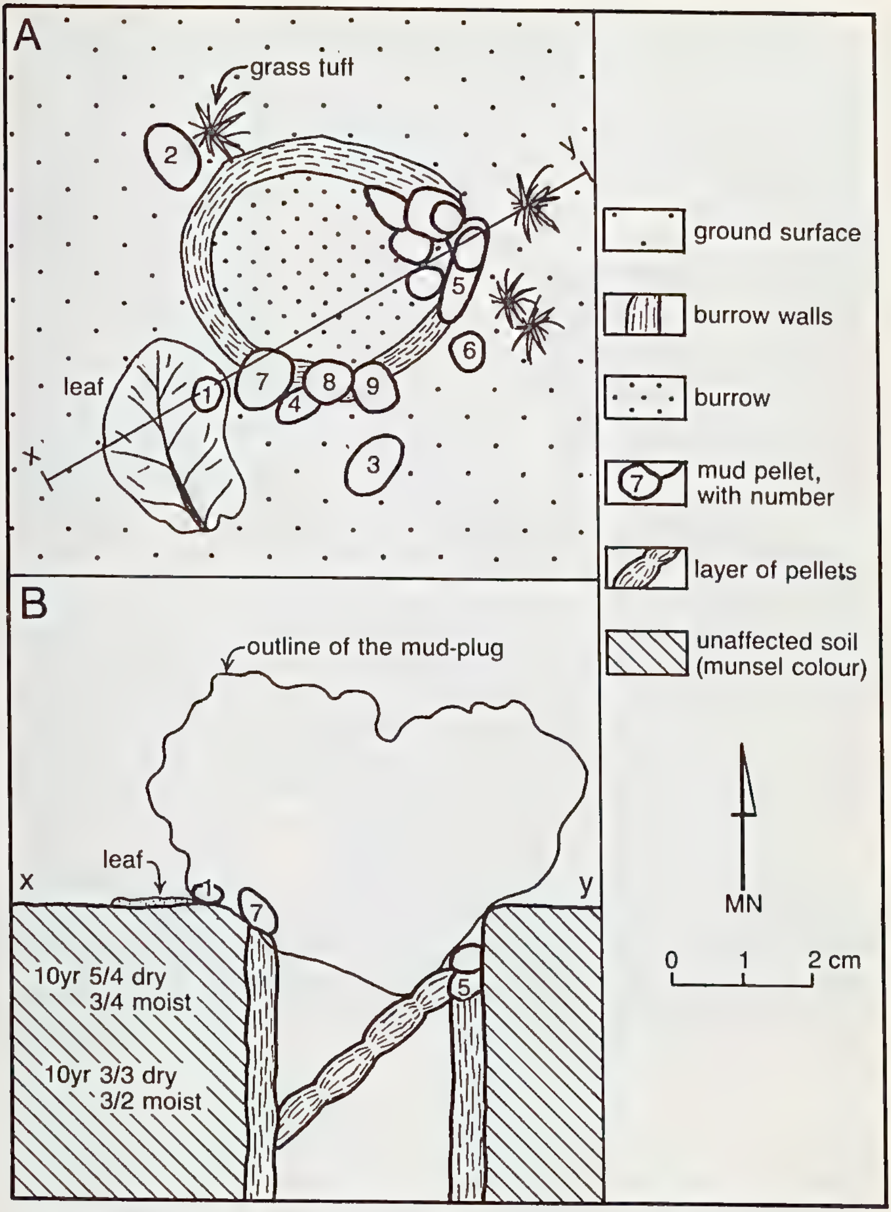

Fig. 1. Burrow entrance of the cicada nymph *Cyclochila australasiae*.

A. Plan view from above of the burrow entrance.

B. Cross section through the burrow entrance showing the position of the inclined plane of pellets that sealed the burrow and the approximate position of the mud-plug.

(Fig. 1B). The burrow was sealed with a layer of another sixteen pellets (Fig. 1B). The burrow was again covered and checked daily. On the morning of the 10th May a plug of mud was found to block the upper part of the burrow above the seal made on 4th May. The burrow was excavated and the nymph extracted. Unfortunately the nymph was misplaced but there seems little doubt it was that of the "greengrocer/yellow monday", *Cyclochila australasiae*, a known turret builder and a common species in suburban Sydney. Whilst under observation this nymph was always covered in a thin moist coating of mud.

The Pellets

The pellets deposited on the 4th May ranged in size from 5 x 3.5 x 3 mm to 10 x 7 x 5 mm (length of principal axes) with a maximum cross-sectional area ranging from 17 to 85 mm^2. This size range agrees closely with the dimensions of the nodules on the external face of the turret and the mud-plug which are described in the next section.

In bringing a pellet of wet mud to the surface the nymph, which always travelled head first, employs one of two techniques. In the first the pellet is wedged between the tarsus and the spines and comb of the enlarged femur of either front leg and the pellet is dragged up the burrow. In the other, the pellet is pushed forward by the conical shaped head which imparts a distinct groove in the pellet. Once at the surface the nymph spends 40 to 290 s depositing the pellet. Some difficulty occurs when an attempt is made to deposit the pellet since it is sticky and adheres to the nymph. To dislodge the pellet the tarsus of the other front leg is used in a scraping action or as an alternative, the whole body is slid over the surface. Nevertheless, once commenced this process takes about 30 s only. After completing this procedure the nymph descended the upper 13 cm of observable burrow at speeds ranging from 1.9 to 4.3 mm/s but the trip was punctuated by rests up to 90 s. The distribution pattern of the pellets deposited immediately after the vial was removed on the 4th May was random (Fig. 1A) with pellets nos. 1-3, 6 deposited at the surface away from the burrow. Pellets nos. 4, 7-9 were deposited at the junction of the burrow edge with the ground surface in a cluster whilst pellet no. 5 together with another six (not numbered) were deposited in a cluster on the broken side of the burrow within 12 mm of the surface. From this cluster another ten pellets were deposited in a downward sloping plane from northeast to southwest (Fig 1B).

Earthen Structures

(i) The turret.

The turret as found on 30th April was 95 mm high, hollow, slightly conical with a curved top, a circular cross section with an external basal diameter of 60 mm tapering to 45 mm and an internal basal

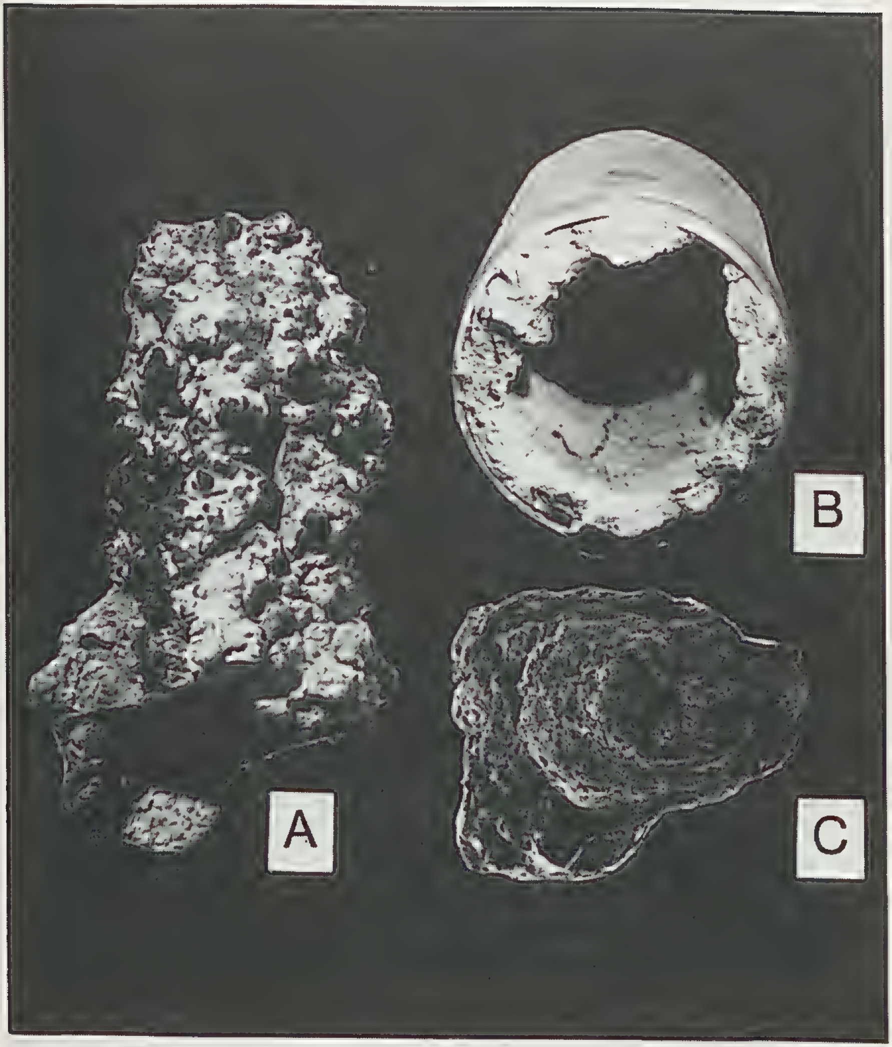

Fig. 2. Earthen structures built by the cicada nymph *Cyclochila australasiae*. (A). The turret. The lower protuberance on the left is part of the burrow lining (see Fig. 1). Note the nodular outer surface of the turret proper and the much smoother inner surface. The darker patches are glue stains and the gaps in the turret wall resulted from attempts to repair the turret following breakage. Total length 116mm, turret proper 95mm. School of Earth Sciences, Macquarie University Museum code MU36068. (B). The mud-lined vial as viewed from open end. Vial diameter 37 mm. Museum code MU36069. (C). The mud-plug as viewed from the bottom end of the plug. Length 60 mm. Museum code MU36070.

diameter of 30 mm (Fig. 2A), and weighed 120 g air dried. Externally it has a very nodular appearance and individual mud pellets 3 to 10 mm diameter are easily discerned. In contrast the internal wall is much smoother and is similar to the 4-5 mm thick lining within the burrow (Fig. 1B). Nodules (pellets) from the turret consist of zones of fine sandy clay loam and fine sandy clay textures which are collectively referred to in this paper as 'mud'. Thin section analysis shows that each zone is composed of poorly sorted quartz sand, ironstone and shale particles (largest up to 4 mm), charcoal, plant fragments, and a clayey matrix. As the turret was located on an suburban lawn it is unlikely that it was more than a few days old at the time it was found.

The general appearance and size of this turret matches closely those of *M. septendecim* as described by Marlatt (1907) and Snodgrass (1934).

(ii) The mud-lined vial.

The plastic vial was lined (up to 1 cm thick) with 51 g (air dry) of mud similar to the mud in the turret. As this emplacement occurred during 88.75 h the minimum rate of deposition or turret construction was about 0.6 g/h (Fig. 2B).

(iii) The mud-plug.

The mud-plug was 'T' shaped with maximum dimensions of 60 x 50 x 45 mm and weighed 80 g (air dry). A narrower protuberance, 3 cm diameter, occupied the opening of the burrow. In comparison with the turret and the mud-lined vial, which were hollow, the mud plug was solid yet discrete mud pellets were readily discernible. As the plug was deposited in one day (9-10th May) the minimum rate of deposition was 3.3 g/h (Fig. 2C).

Turret Construction

As no direct observations of the turret 'proper' (Fig. 2A) were made its construction can only be inferred from its physical appearance and the subsequent activity of the nymph.

The general appearance of the turret, in particular the nodular external face, is consistent with the inference that it is built by the accumulation of individual mud pellets being placed side by side and stacked in an overlapping pattern. The somewhat smoother internal wall is probably formed by the nymph patting or ramming the pellet to smooth it over. Perhaps additional liquid (water) is used to achieve this smoothing process. To achieve this the nymph need only secrete some of the liquid (probably xylem fluid as described by White and Strehl, 1978) stored in its swollen abdomen (Fabre, 1921 in Myers, 1929). Fabre (1921) reports that in dry soil nymphs obtain the necessary moisture by this means. Whether or not smoothing occurs

concurrently with building or as a separate process conducted after most of the building is completed is not known.

The internal diameter of the turret is probably governed by the space required for the nymph to turn around. What determined the final turret height is not known but judging by the thickness (strength) of the turret's base it seems that the turret could have been higher. (Marlatt (1907) records many instances of turrets up to 100 mm high and some 150 to 200 mm high.

The mud used for the pellets deposited at or near the surface on 4th May came from a depth of 13 to 40 cm. On this day individual pellets were dragged up this distance and deposited. The turret was possibly made the same way. The occurrence of the mud-plug, however, may be evidence that soil material is brought near the surface and stored before being used to build a turret. Using this strategy a nymph could build its turret more quickly with the added advantage of lessening the time the open burrow is exposed to possible predators. Alternatively the mud plug was built to seal the burrow.

Why was a Turret Built?

The building of the turret and associated activity occurred during the latter half of autumn. As this is a period when the above ground activity of cicadas is normally minimal it is necessary to seek an explanation. Marlatt (1907, p. 96) considered this problem for *M. septendecim* and suggested a multiple hypothesis.

A complete hypothesis, therefore, seems to be in a union of the explanations offered, namely, that the cone-building habit is induced either by a shallow soil, proximity of the pupae to the surface, or conditions of unusual warmth which brings the pupae to the surface in advance of their normal time, and more rarely to unfavourable conditions of excessive moisture. The mud caps are to protect the burrow from cold until the time of issuing arrives.

In relation to *C. australasiae*, however, Moulds (1982) favours waterlogging of the soil as the key factor whereas Musgrave (1923) prefers the idea that turrets are built by those nymphs that have reached the surface before they are ready to emerge. Of all of these postulated hypotheses that of shallow soil and poor drainage can be eliminated as the burrow extended to 40 cm depth in a well drained soil. This leaves the possibilities of unusual warmth and/or proximity to the surface to consider.

The 10 day period during which the activity was observed was drier, finer and warmer during the day and had a higher morning humidity than during the previous month (Table 1). Perhaps the more favourable climatic conditions at this time initiated activity in the nymph as it prepared itself for final departure prior to ecdysis. The

lining of the vial during this period of mild weather is consistent with this meteorological explanation. Such preparations were possibly thwarted on the afternoon of 9th May when a cool change resulted in lower temperatures and 6mm of rain. During this change the mud plug was probably constructed and may represent an attempt by the nymph to seal the burrow thoroughly, or, as suggested previously, to store soil material ready for the construction of another turret.

A meteorological explanation is however, not entirely satisfactory since only one turret was found at this site even though in the preceding and following summers many open burrows were observed. Perhaps this particular nymph was more mature and/or closer to the surface and thus more responsive to suitable environmental changes than its fellows.

Even though it has not been possible to explain precisely why a turret was built it is of interest to note that, with the exception of the mud-plug, the events and conditions recorded are consistent with those reported for *M. septendecim* by Marlatt (1907).

Other Turrets

The deposition of soil material at the soil surface in the form of a turret (and mud-plug) is an example of 'mounding' by soil mesofauna. High rates of turret construction would imply that cicada nymphs are important in terms of our understanding of how some topsoils are formed and modified (e.g. Humphreys and Mitchell, 1983). In order to secure additional information a search for turrets was undertaken at Epping and at two other study sites, Cattai and Cordeaux (all within 70 km of Sydney), where detail studies on other soil mesofauna (ants, termites etc.) were being conducted.

Despite a search over two summers, 1979-80 and 1980-81, the broken remains of only one additional turret was found - at Cattai on a Yellow Podzolic soil. The remains of this turret, about 21 g (dry weight), was extremely fragile having a fine sandy loam texture i.e. it was dominated by sand (quartz) and a small amount of clay to act as a weak binding agent. A turret of this composition would easily break down to single grain sands by wind gusts, and the impact of rain drops or even falling twigs. It is most unlikely that this type of turret would survive for more than a few days when exposed to the natural elements. Though *P. moerens* was the only cicada species found at this site it is thought that the range of *C. australasiae* extends to this area too. The builder of this particular turret remains uncertain.

Conclusion

The building of turrets by cicada nymphs is probably rare in Australia and to date this activity is known definitely for only one species, *C.*

australasiae. However, there are two cautionary remarks to be made about the uncommonness of turrets in Australia. Firstly, turrets built of sandy materials (and many soil types in Australia have sandy topsoils, c.f. Stace et al., 1968) will be very fragile, easily broken down to single grain sand, and therefore difficult to detect even by skilled observers. Secondly, it is of interest to note that in the USA prior to 1884 the occurrence of turrets built by *M. septendecim* was thought to be rare. However, once known to observers of this species their occurrence was considered commonplace (Marlatt, 1907). Whether or not this will prove true in Australia must await the test of time. Nevertheless, there is another way in which cicada nymphs alter the soil during the excavation of a burrow. In the USA Snodgrass (1921, p. 386) reports that nymphs "...excavate a closed cavity by crowding earth back into the surrounding earth" and Hugie and Passie (1963) noted that nymphs backfill their burrows with soil material derived largely from the soil horizon they are operating in. Presumably either or both of these mechanisms are employed by Australian cicadas. The importance of this action must be potentially greater than turret building if only for the fact that all nymphs form a burrow. However, this topic requires further research.

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References

FABRE, J.H., 1921. Souvenirs entomologiques (cinquième serie). Paris. 12 me ed. Chs. 13-17. Reference not seen but it is quoted in Myers (1929).

HUGIE, V.K. and PASSEY, H.B., 1963. Cicadas and their effect upon soil genesis in certain soils in southern Idaho, northern Utah, and northeastern Nevada. *Proceedings Soil Science Society of America* **27:** 78-82.

HUMPHREYS, G.S., 1981. The rate of ant mounding and earthworm casting near Sydney, New South Wales. *Search* **12:** 129-131.

HUMPHREYS, G.S., 1985. Bioturbation, rainwash and texture contrast soils. Unpub. Ph.D thesis, Macquarie University, N.S.W.

HUMPHREYS, G.S. and MITCHELL, P.B., 1983. A preliminary assessment of the role of bioturbation and rainwash on sandstone hillslopes in the Sydney Basin. *In*: R.W. Young and G.C. Nanson (eds), Aspects of Australian sandstone landscapes. *Australian and New Zealand Geomorphology Group Special Publication* **1:** 66-80.

MARLATT, C.L., 1907. The periodical cicada. *Bulletin United States Department of Agriculture Bureau of Entomology* **71:** 1-181.

McKEOWN, K.C., 1942. *Australian Insects. An introductory handbook.* 304 pp. Royal Zoological Society of New South Wales.

MOULDS, M., 1982. Summertime is cicada time. *Australian Natural History* **20:** 429-435.

MUSGRAVE, A., 1923. The yellow monday cicada. *Australian Museum Magazine* **1:** 204-208.

MYERS, J.C., 1929. *Insect singers. A natural history of the cicadas.* Pp. xix-304. George Routledge and Sons Ltd., London.

SNODGRASS, R.E., 1921. The seventeen-year locust. *Report of the Board of Regents of the Smithsonian Institution* **1919:** 381-409.

SNODGRASS, R.E., 1934. Insects their ways and means of living. *The Smithsonian Institution Series* **5:** 362

STACE, H.C.T., HUBBLE, G.D., BREWER, R., NORTHCOTE, K.H., SLEEMAN, J.R., MULCANY, M.J. and HALLSWORTH, E.G., 1968. *A handbook of Australian soils.* Pp. xii + 435. Rellim Technical Publications, South Australia.

THEOBOLD, W., 1882-1883. *Burma, its people and productions; or, notes on the fauna and flora and minerals of Tenasserim, Pegu and Burma.* Vols 1 and 2. Stephen Austin and Sons, England. N.B. This is a rewritten work of a book with a similar title by Father Mason in 1860. The original work was unavailable to the author.

WHITE, J. and STREHL, C.E., 1978. Xylem feeding by periodical cicada nymphs on tree roots. *Ecological Entomology* **3:** 323-327.

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